

A Comparison of Ammonium and Nitrate Nitrogen for Blueberries¹

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IN New York State the primary problems with the highbush blueberry are those of the home gardener or small grower who has a few plants for local markets. As relatively little land is available that is naturally suitable for the growth of blueberries, many small plantings exist and others are being made on soils where they frequently grow poorly or fail completely.

As a result of many inquiries as to how to improve the growth of these plants a number of small scale experiments have been conducted in an attempt to learn more about the nutritional requirements of the blueberry plant.

The failure of blueberries to grow is usually associated with soils with a pH above 5.5 and is accompanied by a yellowing of the foliage of the type commonly known as "lime induced chlorosis" or "iron deficiency".

REVIEW OF LITERATURE

A number of investigators (4, 8, 11, 12) have stressed the importance of soil acidity for blueberry growth suggesting a range of pH 4.0 to 5.2, above or below which blueberries may not be expected to survive, and have recommended methods of soil acidification (8, 11). Merrill (14) obtained increases in yield and growth from applications of limestone to soils below pH 4.0 and Baily (1) obtained detrimental results from liming a soil at pH 4.6. Harmer (11) suggested that the poor growth at high pH levels may be due to too much calcium, magnesium and nitrates in the soil although specific toxicity from these elements has not been demonstrated.

Soil structure, aeration, organic matter and water are stressed by Boller (6) as being the most important factors in blueberry culture, indicating successful plantings over a wider range of soil acidity if these conditions are satisfactory. Cain (7) agrees with these conclusions, reporting successful blueberry plantings on soils above pH 6.0 with the use of ammonium sulfate fertilizer and sawdust mulch, and healthy plants grown in nutrient solutions at pH 6.5 when adequate nutrient supply is maintained.

Spraying the foliage with soluble iron salts has been recommended (5) to correct the chlorosis associated with high pH soils but this is only a temporary corrective measure, the chlorosis usually reappearing on new growth made after the spray application. Baily and Everson (2) corrected chlorosis with ammonium sulfate or aluminum sulfate and found more soluble iron in the soil under these conditions, indicating a lack of iron availability in the soil as a cause of the chlorosis. Willis and Carrero (16) produced chlorosis in rice with several

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forms of nitrate nitrogen and corrected it with ammonium sulfate. They suggested that an "unassimilable ion" caused precipitation of iron within the plant resulting in chlorosis.

Beckwith (3) suggests that ammonium sulfate gives better results in soils above pH 5.5 and Doehlert (9) recommends its use in connection with lime on commercial blueberry plantings. Doehlert and Shive (10) using sand culture methods indicate that blueberries absorb ammonium nitrogen better than nitrate at high pH values in the nutrient solution. However commercial fertilizer recommendations for blueberries usually contain nitrate as the principal source of nitrogen (4, 9, 13).

MATERIALS AND METHODS

The plant material used in all experiments reported herein were one-year-old cuttings of highbush blueberries rooted in a half and half mixture of peat and sawdust. The cuttings were taken directly from the propagating bed, washed to remove as much of the rooting medium as possible and selected for uniformity of size of both top and root system. The tops usually consisted of a single shoot six to eight inches long.

In the sand culture experiments the plants were set in three gallon glazed crocks in quartz sand, one plant per crock. The crocks were irrigated twice daily from the bottom by an automatic air pressure system forcing the nutrient solution up into the sand from a five gallon carboy of nutrient solution. Three crocks were usually irrigated from each carboy of nutrient solution.

In the pot experiment the plants were set in eight-inch clay pots in a half and half mixture of greenhouse potting soil and sawdust. The nutrient solutions were applied once each week to the surface of the pot with sufficient intermittent watering to keep the surface of the soil wet but not enough to cause leaching.

EXPERIMENTAL RESULTS

Experiment 1:—In 1948 a sand culture experiment was set up to test the tolerance of blueberry plants to calcium. There were six treatments of three plants each in which the calcium was varied from 20 ppm to 300 ppm by substituting calcium nitrate for ammonium nitrate in the nutrient solution² in such a manner as to keep the total nitrogen constant at 210 ppm. This resulted in increasing the nitrate and reducing ammonium nitrogen so that the highest calcium level had calcium nitrate as a sole source of nitrogen. The pH of the nutrient solutions was maintained below 5.5 by weekly adjustments.

By the middle of the summer all plants appeared to have made about equal growth but all three plants at 300 ppm of calcium (Table 1) showed marked yellowing of the young foliage characteristic of iron deficiency symptoms. Extra additions of iron tartrate to this culture temporarily corrected the chlorosis but it reappeared after a period of about a month. In late August 70 ppm of ammonium nitrogen (as am-

².002M.MgSO₄, .003M.KCl, .002M.(NaPO₃)_x plus Fe, Mn, Cu, Zn, B and Mo in standard "trace" quantities.

Table 1. The effect of calcium on growth and on the mineral composition of the foliage of Jersey blueberry cuttings.^a

Calcium supply (ppm)	Linear growth (cm)		Per cent of dry foliage					PPM	
	1948	1949	N	Ca	Mg	K	P	Mn	Fe
20	285	819	—	0.41	0.15	1.64	0.16	303	170
60	350	1,261	2.61	0.43	0.13	1.23	0.15	297	138
120	330	1,148	2.38	0.49	0.13	1.35	0.13	253	116
180	410	1,301	2.36	0.62	0.12	1.33	0.14	334	76
240	375	1,017	2.15	0.72	0.10	1.83	0.11	357	72
300	300	864	1.88	1.25	0.14	1.86	0.13	361	279 ^b

^aEach figure is an average of three plants.

^bExtra iron added when chlorosis appeared.

monium nitrate) were added to this culture because this was the only ingredient of the nutrient solution lacking in this culture that all other cultures contained. Within two weeks the chlorosis began to disappear and by the end of the season these plants could not be distinguished from the other plants in foliage color.

Table 1 shows the growth and foliage composition of these plants at the end of the season. The calcium content of the foliage is approximately proportional to the calcium supply with a concurrent decrease in nitrogen, magnesium, phosphorus and iron. However, there was also a decrease in the supply of ammonium nitrogen (with total nitrogen constant), none being supplied to the last culture until late in the season. The significant points here are: 1. that the nitrogen and iron content vary with the supply of ammonium nitrogen and 2. the high iron content of the last culture, which had additional iron added because of its persistent chlorosis during most of the season, the latter disappearing only upon the addition of ammonium nitrogen to the solution. These observations prompted the following experiments.

Experiment 2:—Since it has been observed in the field that blueberry plants respond to ammonium sulfate fertilizer more than could be attributed to the slight change in soil pH observed and also in view of the above observation on the apparent influence of ammonium nitrogen on growth and perhaps iron metabolism within the plant, an experiment was set up to compare several sources of both ammonium and nitrate nitrogen for blueberries in a soil of pH 7.0. The soil was mixed with sawdust to provide adequate drainage, aeration and organic matter.

Each treatment consisted of ten plants set in 8 inch clay pots and paired for uniformity of size. Each pot was irrigated once each week with 250 milliliters of a solution containing 350 ppm of nitrogen from its respective source, using reagent grade chemicals for the stock solution. Treatments were continued for 16 weeks starting when the first leaves appeared. All pots were set in randomized blocks on the greenhouse bench.

Table 2 shows the data obtained at the end of the first season. The soil pH was lowered somewhat by all of the ammonium compounds but in no case did it fall below pH 6.0. The growth and appearance of all plants receiving ammonium nitrogen except ammonium hydroxide, were outstandingly superior to those receiving nitrates. The foliage

Table 2. The effect of various sources of nitrogen on growth and leaf composition of Rubel blueberry cuttings in potting soil.^a

N Source	Leaf weight (mg)	Leaf rating ^b		Growth (cm)	Soil pH ^c	Leaf composition						
		Fe-Def.	N-Def.			Per cent of dry weight					Ppm	
						N	Ca	Mg	K	P	Fe	Mn
NH ₄ OH	51	3.0	2.4	58	6.7	1.9	0.63	0.17	0.78	0.07	85	196
NH ₄ Cl	65	1.0	1.4	194	6.1	2.3	0.73	0.17	0.43	0.09	68	217
(NH ₄) ₂ SO ₄	88	0.5	1.6	253	6.2	2.4	0.56	0.14	0.49	0.08	64	162
(NH ₄) ₂ HPO ₄	73	0.1	1.4	298	6.1	2.3	0.68	0.17	0.59	0.20	73	180
NH ₄ NO ₃	75	2.0	2.4	105	6.6	1.8	0.54	0.13	0.52	0.07	60	131
Ca(NO ₃) ₂	42	2.3	3.3	31	7.1	1.2	0.54	0.14	0.85	0.06	67	135
K NO ₃	57	1.8	2.8	34	7.5	1.1	0.33	0.12	3.03	0.06	75	109
Na NO ₃	53	1.8	3.6	32	7.6	1.2	0.33	0.09	0.61	0.04	78	122
H NO ₃	65	1.0	2.6	112	6.5	2.0	0.50	0.13	0.94	0.07	75	146
NaCl	11	—	4.8	7	7.1	1.2	0.69	0.24	0.97	0.06	144	122

^aEach figure is an average for ten plants. Leaf analysis was made on duplicate composite sample of 5 plants each in each treatment. All data taken at the end of one season's growth in the green house.

^bArbitrary ratings from 1 to 5 with increasing severity of visual symptom.

^cInitial pH of soil was 7.0.

was arbitrarily rated for both iron and nitrogen deficiency but it was difficult to distinguish these on the nitrate plants because of the acute symptoms. Nearly all leaves were small, pale yellow in color frequently tinged with red. The plants receiving ammonium generally had a healthy green color with occasional tip leaves showing the characteristic mottled chlorosis of iron deficiency. The plants receiving ammonium hydroxide had a good appearance and made fair growth until mid-season being very similar to the other plants receiving ammonium at that time. However, in late summer they became pale green in color and stopped growing. By the end of the season the leaves were quite yellow. An examination of these pots showed poor drainage and a water logged condition in the soil probably caused by the dispersion of the soil colloids by the ammonium hydroxide.

Foliage analysis shows about twice as much nitrogen in the plants receiving ammonium as in those receiving nitrate nitrogen, and slightly more calcium, magnesium and manganese, with no difference in potash and phosphorus except where the source of nitrogen contained these elements.

These data indicate that 1. ammonium nitrogen is superior to nitrates and perhaps essential for blueberries under these soil conditions, 2. that iron deficiency symptoms (chlorosis) are not necessarily related to soil pH, calcium content or the iron content of the foliage, since the healthiest plants had more calcium and sometimes less iron than those showing acute chlorosis and making very poor growth, and 3. ammonium nitrogen was absorbed and utilized more readily than nitrates, as indicated by twice as much nitrogen in the foliage and from three to eight times as much linear growth. It also may be involved in the internal iron nutrition of the plant as it virtually prevented iron deficiency symptoms without any change in the iron content of the foliage.

Experiment 3:—Because of the fact that there was a slight pH change in the soils treated with ammonium nitrogen in the above ex-

periment that possibly influenced the results, another sand culture experiment was started in 1951 to compare the growth of blueberry plants using ammonium chloride and nitrate of soda as the sources of nitrogen in nutrient solutions in which the pH was maintained below 5.2 by adjustments every two or three days. The growth data for these plants are shown in Table 3, together with growth data from another series in sand culture comparing ammonium chloride with ammonium nitrate at three levels of nitrogen. Iron was supplied to all solutions in the form of iron tartrate at 10 ppm of iron.

Table 3. The effect of ammonium and nitrate nitrogen on the growth of blueberry cuttings in sand culture.^a

Jersey cuttings 1949			Rubel cuttings 1951				
N supply (Ppm)	Linear growth (in.)		N supply (ppm)	NH ₄ Cl		NaNO ₃ ^b	
	NH ₄ NO ₃	NH ₄ Cl		No. shoots	Ave. length (in.)	No. shoots	Ave. length (in.)
28	193	217	140	7.0	15	6.0	3.0
56	200	247	140	5.0	13	5.0	6.0
112	237	289	140	5.0	17	5.0	4.0
Mean	212	251	Mean	5.7	15	5.3	4.4

^aEach figure is an average of three plants irrigated from the same solution carboy. The pH of the solution was kept below 5.2 by adjustment when necessary.

^bAll plants in this series showed severe chlorosis.

The plants on nitrate of soda made very poor growth and were extremely chlorotic throughout the season whereas those on ammonium chloride grew vigorously and were a healthy green color.

In the comparison with ammonium nitrate the growth was slightly less in ammonium nitrate than ammonium chloride even when compared on the basis of equivalent ammonia nitrogen. This is suggestive that nitrate nitrogen may be harmful to growth.

SUMMARY AND CONCLUSION

Evidence is presented which indicates that ammonium nitrogen is superior to nitrate for blueberries and may be essential, and that nitrates may actually be harmful to the plant. It is also shown that ammonium nitrogen may be in some way associated with iron nutrition. This apparently is not an effect on the availability of iron in the solution or absorption by the roots but on internal function, since plants receiving nitrate nitrogen and showing iron deficiency symptom contain as much or more iron in their foliage as those showing no symptom of deficiency.

Soil pH may not necessarily be a direct controlling factor in iron absorption because plants growing on soils of relatively high pH often contain as much iron in their foliage as those growing at a lower one.

It is suggested that one of the reasons for the failure of blueberry plants on marginal soils may be a lack of ammonium nitrogen. Soil conditions prevailing where these failures occur usually are favorable for the growth of nitrifying organisms resulting in a high concentration of nitrates. Ammonium nitrogen is short-lived under such conditions.

On the other hand, in acid soils naturally favorable for blueberry growth denitrifying organisms predominate and nitrates are quickly converted into the ammonium form.

Further work on the interrelationships between soil acidity, form of nitrogen and iron nutrition are needed before a clear picture of these factors can be formulated.

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